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First Bimonthly Report
Of The
Miniature IF Amplifier Program

Period: 1-July-1959 to 1-Sept.-1959

[Redacted]

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Prepared by:

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I. Purpose

As described in the "Proposal For The Construction Of Miniaturized IF Amplifier Packages," dated 9-March-1949, the purpose of this program is to bring to fruition work previously carried out in the development of IF amplifiers using novel techniques and devices.

Two miniaturized IF amplifier packages will be constructed. One will be suitable for a single conversion superheterodyne receiver and will employ a miniaturized crystal filter as the bandpass determining element. This filter will be built using the techniques developed as a result of work performed under the continuation of the Radio Circuit Study program [redacted] but employing crystals fabricated specifically for this application rather than standard units.

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The second packaged amplifier will consist of a high and low IF amplifier combination with mixer and crystal controlled local oscillator stages, suitable for use in a double conversion receiver. In the low IF amplifier, bandwidth determination and interstage coupling will be by means of ceramic resonators rather than conventional inductors and capacitors. Techniques for using these ceramic components were developed during the original Radio Circuit Study [redacted] but were subsequently discontinued because at that time no material was available which was sufficiently temperature stable. The materials problem has now been largely solved and ceramic transformers meeting center frequency stability requirements over the temperature range from -40° to +40°C can be fabricated.

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At the conclusion of this program two miniaturized IF amplifier

packages will be delivered. They may then be evaluated and compared with respect to temperature stability, physical size, battery drain, etc.

II. Abstract

This report, covering the first two-month period describes the preliminary work which has been performed in the two amplifier programs. The amplifier for the single conversion receiver employs a crystal filter. Initial efforts have been concerned with the design and construction of this filter which, while very small (one cubic inch), will be the largest single component in the amplifier and will consequently have a profound effect on the packaging of the remainder of the components.

For the second amplifier, preliminary work has been concerned with the preparation of suitable ceramic from which to fabricate the lumped filter and the interstage coupling transformers. From the materials prepared, transformers have been built and measurements of their electrical performance made. Some circuit work has been carried out in order to evaluate the transformers under conditions which are similar to those existing in the final amplifier.

III. Factual Data

(a) Crystal Filter Program

During previous programs the problems of realizing a miniaturized filter suitable for use in a single conversion 3-30 MC receiver have been studied. In the interests of image rejection, a high IF frequency is desirable whereas for narrow passbands a low IF frequency is more suitable. A filter

with suitable bandpass characteristics operating at a relatively high IF frequency can be designed making use of the properties of crystals. However, commercially available crystal filters are quite large, making their use in highly miniaturized equipment very difficult.

Some work was done on the development of a miniaturized crystal filter under a previous program. The resultant filter was substantially smaller than anything then commercially available. It utilized, however, commercially available crystals.

The development of the present miniaturized crystal filter is being carried out with the benefit of the experience and equipment of [REDACTED]

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[REDACTED] This group, located in [REDACTED] is in a position to grind and mount crystals specifically for the present application.

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During the present reporting period a technique has been developed for mounting crystals operating in the 2 MC range in standard type HC-18/U holders. The intermediate frequency to be used in the present amplifier is 2.281 MC. Various methods of grinding quartz crystal blanks have been investigated in order to arrive at a satisfactory procedure for reducing spurious response. With the edges of both sides of the crystal beveled, spurious response of the individual crystals is reduced to -40 db or better at a spacing of approximately 250 kc from the crystal frequency.

The electrical circuit will take the form of a two-section, half-lattice filter. Exclusive of crystals, the transformers at both input and output of the filter will be the most critical elements. Transformer core

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materials supplied by a number of manufacturers have been evaluated. A material will be selected to satisfy the requirements of Q, inductance and temperature stability while conforming to physical size specifications.

(b) Ceramic Resonator Program

A program of materials evaluation and development has been conducted in the [redacted] as a joint effort of the [redacted]

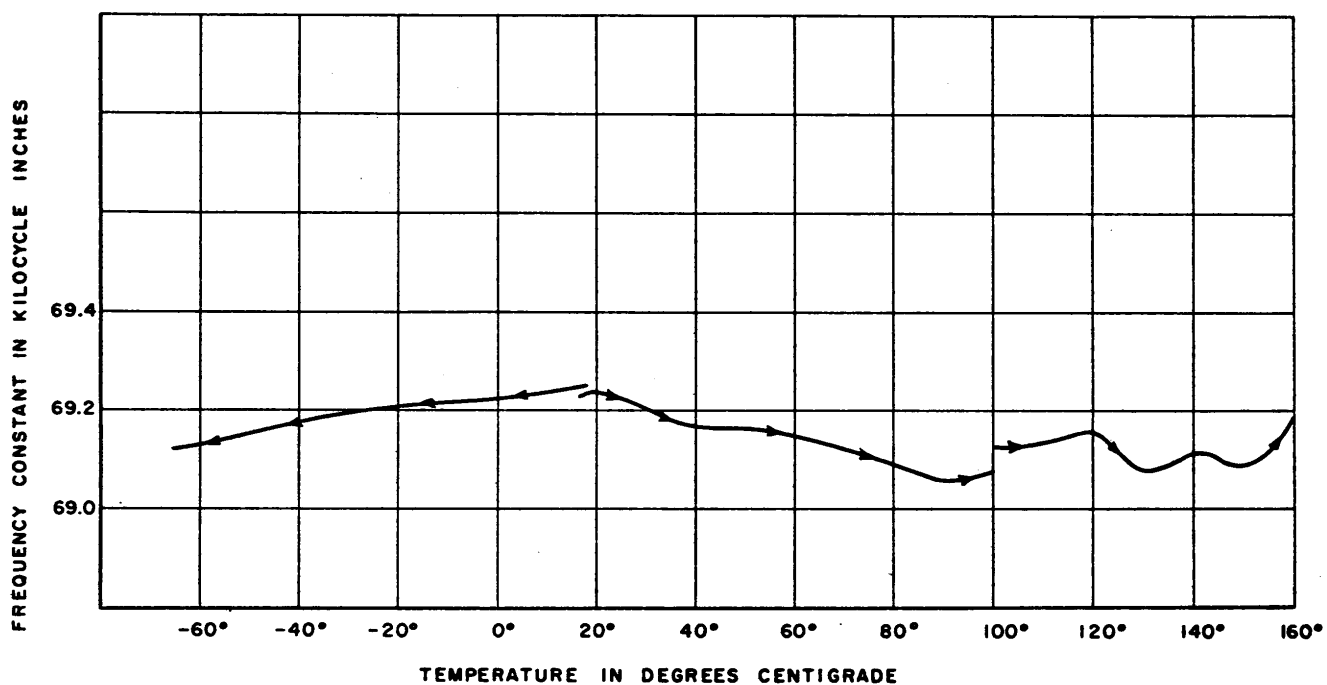
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One of the experimental materials recently fabricated and evaluated has a temperature stability that makes it suitable for use over the temperature range from -65° to $+160^{\circ}\text{C}$. A curve of the frequency constant (resonant frequency normalized to a one inch sample) variation with temperature of this material is shown in Figure 1. Over the whole temperature range there is less than a .3% change in the frequency constant. For the range of interest to this program, there is less than a .2% change of frequency (-40°C to $+40^{\circ}\text{C}$.)

Several ceramic transformers for use as interstage coupling elements in the transistor amplifier were fabricated from this material. However, when these transformers were tried in the transistor amplifier breadboard circuit, the bandwidth of a single stage was found to be too narrow.

The bandwidth of such a single stage circuit is a function of several factors. The bandwidth of a ceramic transformer interstage coupler depends on both the ceramic material properties and the terminating impedances used with it. In this case the terminating impedances are the output impedance of the preceding transistor and the input impedance of the succeeding transistor.



FREQUENCY CONSTANT VERSUS TEMPERATURE

FIGURE 1

The ceramic material properties of importance are the electro-mechanical coupling coefficient and the mechanical Q. A low coupling coefficient will increase the insertion loss of the ceramic element and decrease the bandwidth, while a high mechanical Q will decrease the insertion loss and decrease the bandwidth. The coupling coefficient of this experimental material is considerably in excess of that required for this application. The trouble lies with the mechanical Q. With the terminating impedances, which are largely capacitive, supplied by the transistors used in this amplifier, the bandwidth is primarily a function of the mechanical Q of the ceramic transformer material and will increase as the mechanical Q is decreased. This experimental material is therefore unsuitable for this application as it stands, unless a new transistor or a new operating point for the transistors can be found such that the capacitances of the transistor input and output can be decreased.

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that it is possible to fabricate a new material with essentially the same temperature stability and a lower mechanical Q. Such a modified material will be attempted and available for evaluation in the near future. Meanwhile some ceramic transformers are being fabricated from other ceramic materials with less but possibly sufficient temperature stability and lower mechanical Q.

As stated earlier the bandpass characteristics of a ceramic transformer are to a significant extent a function of the terminating impedances on either side of the transformer. For this reason it is important, in evaluating the transformers, to do so in a circuit configuration which is similar to that in which they will ultimately be used. Consequently several

stages of the 455 kc amplifier were constructed in breadboard form to serve as a transformer test jig.

The narrow bandwidth exhibited by the transformers which have been tested so far was initially attributed to an excessive input capacitance to the subsequent transistor. A capacitive divider was consequently used at the transformer output to reduce the effective load capacitance. The improvement in bandwidth was quite marginal. Further tests showed that, even when terminated in a pure resistance, the transformer bandwidth was insufficient.

In the interests of minimum size for the amplifier it was planned to use Raytheon CK17 subminiature transistors and initial circuit work has been carried out with this type of transistor. However, when additional units were ordered it was learned that production of these transistors has been suspended. At the time of writing it is not clear when they will become available again.

During the previous program which resulted in the construction of the miniaturized 3-30 MC receiver, an effort was made to use a 2.736 MC crystal packaged in a miniaturized case. It was found however that while room temperature operation was satisfactory, over the temperature range from -40° to $+40^{\circ}\text{C}$ the performance deteriorated. Further work in the crystal packaging field has resulted in what appears to be a satisfactory method of mounting a crystal of as low a frequency as 2.736 MC in a miniature case. If tests show that operation is as satisfactory as it appears, at present, to be, an appreciable volume will have been saved in the design of the local oscillator which will be incorporated in the ceramic transformer IF amplifier package.

IV. Conclusions

The crystal filter work is progressing satisfactorily. Methods have been established for keeping down spurious responses. Other than the crystals themselves, one of the more difficult portions of the filter development is the selection of a suitable core material for the filter input and output transformers. Evaluation of core materials is continuing.

Measurements made of initial batches of ceramic for the interstage coupling transformers to be used in the second IF amplifier package have shown that temperature stability is more than adequate for the present application. However the bandwidth obtainable is not sufficient. This is due to too high a mechanical Q in the material. A second batch of material is being prepared in which it is anticipated that this problem will be solved.

V. Future Plans

No work is scheduled on the crystal filter amplifier itself until after completion of the filter. According to the original plans the filter will be completed by 31-Dec.-1959. At the present time there is no reason to revise this schedule.

The ceramic transformer development is scheduled to be completed by 1-Nov.-1959. Until that time, circuit work will be confined to that necessary to evaluate the transformers and lumped filter as they are fabricated. Despite the bandwidth problem mentioned elsewhere in this report it is not anticipated that any revision of the filter and transformer completion date will be required.

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